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(71) Applicant : WHITBREAD PLC
Brewery, Chiswell Street
London EC1Y 4SD (GB)

(72) Inventor : Lord, Stephen
1 Warwick Drive, Wing
Near Leighton Buzzard, Bedfordshire (GB)
Inventor : Cole, Alan
12 Village Court, Twyford Road
St Albans, Hertfordshire (GB)
Inventor : Robinson, John
15 Lindsey Road, Stopsley
Luton, Bedfordshire (GB)

(74) Representative : Cooke, William Douglas et al
HUGHES CLARK & CO 114-118 Southampton Row
London WC1B 5AA (GB)

(54) Diagnostic equipment.

(57) Diagnostic equipment more particularly to indentify faults in refrigeration equipment is described. The equipment comprises a diagnostic sensor unit (10) including a microprocessor module (21) comprising a microprocessor (22), a ROM (23), a RAM (24), an EEPROM (25), a system clock (26), an analogue to digital converter (ADC) (27) and a digital interface (28) powered by an independent power supply to the equipment being monitored. A plurality of inputs is connected to locations in the refigerated equipment and a display e.g. a liquid crystal display, is provided to indicate the status of the equipment. The input from the locations is learnt by the microprocessor (22) and any change in the input from these locations is compared with the learnt inputs and significant changes are indicated as faults on the display.

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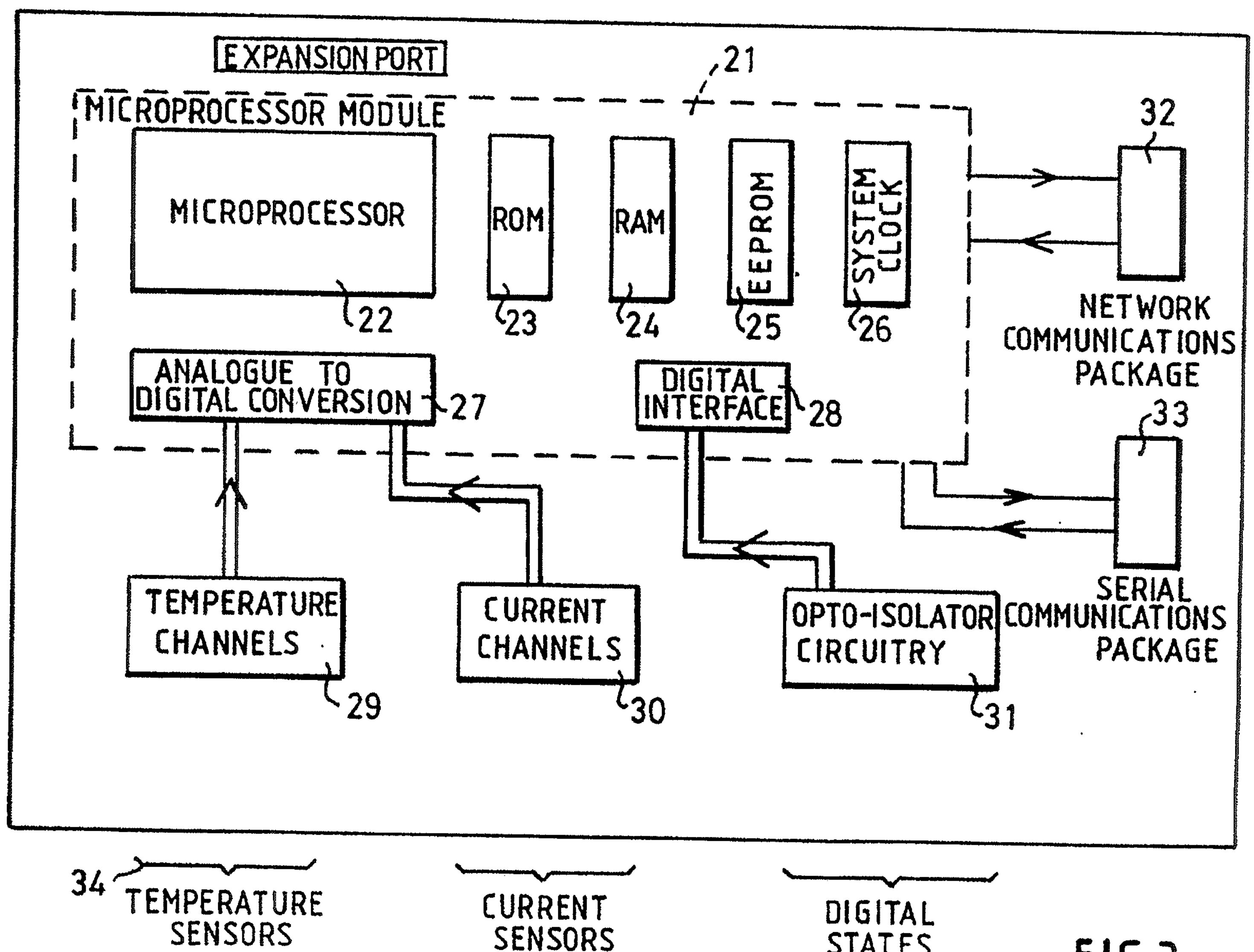
EXPANSION PORT
21
MICROPROCESSOR MODULE
MICROPROCESSOR
22
ROM
23
RAM
24
EEPROM
25
SYSTEM CLOCK
26
ANALOGUE TO DIGITAL CONVERSION
27
DIGITAL INTERFACE
28
32
NETWORK COMMUNICATIONS PACKAGE
33
SERIAL COMMUNICATIONS PACKAGE
TEMPERATURE CHANNELS
29
CURRENT CHANNELS
30
OPTO-ISOLATOR CIRCUITRY
31
34
TEMPERATURE SENSORS
CURRENT SENSORS
DIGITAL STATES

FIG.3.

This invention relates to diagnostic equipment and more particularly to diagnostic equipment to identify faults in refrigeration equipment.

In existing refrigeration equipment a change in the normal operating temperature range only becomes apparent when this is shown by a thermometer or when an alarm is operated. Once the occurrence of a fault has been discovered a technician has to be notified to repair the equipment.

Diagnosis of the fault, which caused failure in the equipment is facilitated by applying 'clip-on' or 'plug-in' test equipment and by manually inspecting and testing each of the refrigerator circuit components e.g. the fans or compressors, until the fault is identified and a repair of the equipment is made.

These known fault diagnostic and repair procedures have the disadvantage that if there is a fault in a refrigeration circuit, then the delay in diagnosing and repairing the fault could result in the loss of the refrigerator contents with the ensuing costs. Additionally a technician could have abortive visits to carry out the repair if he does not carry the required spare part.

An aim of the present invention is to overcome the above disadvantages and provide an <u>in situ</u> diagnostic equipment to identify faults at the earliest opportunity.

According to one aspect of the present invention there is provided a diagnostic sensor unit for monitoring and identifying faults in equipment such as refrigeration units, comprising a microprocessor module powered by an independent power supply to the equipment being monitored, a plurality of inputs for connection to locations in the refrigeration equipment and a status indicator display, wherein the input from the locations is learnt by the microprocessor and any change in the inputs from these locations is compared with the learnt inputs and significant changes indicated as faults on the display.

Conveniently, the diagnostic sensor unit can be connected to a data collection device such as a modem.

According to another aspect of the present invention there is provided a refrigeration circuit comprising at least one refrigeration unit, a plurality of locations, designating physical parameters around the circuit, being connected to a control box, and a diagnostic sensor unit as set forth in the two preceding paragraphs <u>in situ</u> in the refrigeration circuit so that the diagnostic sensor unit monitors and identifies faults in the refrigeration circuit.

An embodiment of the invention will now be described by way of example only with reference to the accompanying drawings, in which:

Fig. 1 is a diagrammatic view of a refrigeration circuit incorporating a diagnostic sensor unit of the present invention;

Fig. 2 is a diagrammatic view of a network system of refrigeration units; and

Fig. 3 is a diagram of an electronic circuit of a diagnostic sensor unit.

The system is designed for the monitoring of faults in, for example, refrigeration equipment and is equally applicable to both single cooling units such as cold cabinets and networked or multiple units (e.g. building air conditioning and public house cellars).

The diagnostics are based upon the system diagrammatically shown in Fig. 1 comprising a schematic view of a typical refrigeration circuit. The circuit comprises a condenser 1 cooled by a fan 2, refrigerant is fed from a compressor 3 to the condenser via a control valve 4 to an evaporator 5 also cooled by a fan 6. The refrigerant circulates in the system to provide a refrigeration unit e.g. a cold store display cabinet. The various electrical units of the system are connected with a controller 7 which can also connect the system with other electric control or protection devices at inputs 8. Each cooling unit 9, indicated in chain dotted line, is monitored by a diagnostic sensor unit (DSU) 10 which receives the inputs from the circuit voltage, controllers, temperatures, currents and pressures at 11. The DSU 10 is also connected with a status indicator display 12 indicating the current status of each device being monitored by the DSU 10.

In the network system of refrigeration units shown in Fig. 2, each refrigeration unit 13 to 16 is monitored by a DSU which indicates the status of the particular device. Individual DSU's are linked on a network cable 17 which supplies the electric power and communication media to the units. The network power supply 18 is generated in a single mains transformer (not shown) capable of supplying up to thirty-two stations.

Control of the network is via a single network controller 19 which is also used as the primary means of indicating faults. The network may optionally be connected with a modem or other data collection device 20 to enable the alarm or details of the faults diagnosed to be recorded or viewed from a remote location.

An embodiment of a DSU electronic circuit is shown in Fig. 3 and comprises a microprocessor module 21 including a microprocessor 22, a ROM 23, a RAM 24, an EEPROM 25, a system clock 26, an analogue to digital converter (ADC) 27 and a digital interface 28.

The ADC 27 is connected with temperature channels 29 and current channels 30, while the digital interface is connected to an opto-isolator circuit 31. The microprocessor module 21 is interfaced with network communications package 32 and a serial communications package 33.

The temperature channels 29 include circuitry which performs the function of interfacing up to six temperature sensors 34 to the ADC 27. The main task of this circuit is to amplify the sensor signals into the correct range of the ADC.

The circuit of the current channels 30 performs an identical task to the temperature channels the main difference being the sine-wave type signals given out by the sensors. Analysis of the signals is actually conducted through the microprocessor.

The opto-isolator 31 is used to monitor for the presence of main voltage in the refrigration equipment.

The microprocessor 22 has a built in ADC and digital ports.

The system ROM chip 23 holds all of the software used by the DSU.

The system RAM chip 24 (Randam Access Memory) holds all the system data and variables while the DSU remains powered up.

The EEPROM 25 (Electrically Erasable Read Only Memory) is used to hold all setup data and a full fault history of the refrigeration unit. The advantage of the EEPROM is that the data is retained even when power has been removed.

The system clock 26 provides the real time clock for use by the microprocessor 22.

The network communications package 32 is an integrated circuit used to translate serial data sent by the microprocessor 22 in the voltage levels used by an RS 485 network. The package also contains a direction pin to determine whether data is being transmitted or received.

The serial communications package 33 is an integrated circuit which is used to translate serial data sent by the microprocessor 22 into the correct voltage levels for RS232 communications. The circuit also includes all of the handshaking procedures required by a modem.

The function of the software is to store and process up to twelve channels of analogue information collected from the refrigeration circuit, temperature sensors and current sensors. Digital states e.g. the power supply on/off are also monitored. Analogue information is stored in a series of buffers (32 bytes per channel).

A sampling window is defined to be active i.e. 'open' when the refrigeration unit is cycling on. When the window is 'open' both temperatures and current information is stored. The oldest sample in the buffer is lost as each new sample is stored.

At each sampling interval the general fault condition of the equipment is checked. Diagnosis of faults is only started when a predetermined learning period has been completed. Faults are identified by comparing the present status of the refrigeration unit with the profile generated during the learning process.

The DSU perfoms all of the diagnostics on the refrigeration equipment and operates as follows:

A series of measurements are made of the physical characteristics located around the refrigeration circuit i.e. temperatures, currents, digital states and any other related physical feature of the equipment being monitored. These readings are then compared with the known characteristics of the equipment and significant deviations from the normal readings are indicated as faults.

A simplified schematic example of one possible application will now be described with reference to Fig. 1. The following designate locations in the refrigeration circuit:

(a) Condenser inlet temperature;
(b) Condenser outlet temperature;
(c) Evaporator inlet temperature;
(d) Evaporator outlet temperature;
(e) Chilled space temperature;
(f) Evaporator fan's current;
(g) Condenser fan's current;
(h) Compressor current.

Thermostat position, mains voltage and status of protection devices.

At the initial set up, the DSU will read the various parameters at the locations around the refrigeration circuit and, by the application of algorithms, will generate a normal operating profile for the refrigeration unit which constitutes the learning process.

Depending upon the on or off operating mode of the refrigeration equipment the DSU will apply a series of tests which compare the operating profile with the 'learnt profile' to determine e.g. whether the compressor current is greater than normal. Faults will then be indicated using the decisions as the basis.

In a network arrangement in, for example, a public house cellar, the fault status of each DSU would be passed back to the network controller. In cases where the DSU is being applied in isolation, faults are communicated using a series of indicator lamps and/or by a modem link.

The type of faults which would be monitored in a cellar cooler would be as follows:

Condenser blocked, Evaporator blocked, Thermostat O/C, LP contact, HP contact mains failure, Thermostat S/C, Evaporator fan failed, condenser fan failed and compressor failed.

The network controller has two main purposes:

(i) scheduling of communications between the various DSU's and the controller;
(ii) display of the faults encountered on each piece of refrigeration equipment.

Each DSU is allocated a station number between one and thirty-two and the controller will then ask each of these stations to transmit their fault status. On receipt of this status information the network controller will display the fault on a liquid crystal display (LCD).

In large systems the network controller will also perform the task of sending out fault status through a modem link. The DSU can also be interrogated using a standard IBM PC type computer or a portable computer unit sold under the trade name PSION organiser.

The network power supply for the DSU's are held

separate from those of the refrigeration equipment to minimise the possibility of a common mode failure i.e. loss of power masking a fault in the refrigeration unit. Network power is generated using standard power supply techniques, the only requirement is for a mains supply.

The DSU of the present invention has a number of advantages over existing monitoring equipment.

1. It is a microprocessor based system which performs passive monitoring and diagnostics on any item of refrigeration equipment.

2. More than sixteen types of fault can be identified on the refrigeration equipment.

3. The DSU is permanently installed in the equipment during manufacture of the equipment to be monitored or retrofitted rather than carried as a portable test equipment.

4. Mains failures can be identified, as separate power supplies are used for the refrigeration equipment and the DSU.

5. The DSU can be configured for operation in either a network or single mode.

6. The self learning facility of the DSU allows it to be matched to the equipment being monitored. When a repair of the equipment is carried out, e.g. a compressor replacement, the learning process can be readily repeated.

7. Complex refrigeration circuits, i.e. split condensers and evaporators and/or multiple evaporators can be accommodated by applying a DSU to each of the evaporators and condensers. The equipment status is then indicated by the network controller each item is thus treated as independent.

8. Different diagnostics are applied to the refrigeration equipment depending upon whether the unit is running, stopped or in an intermediate state.

9. By using physical measurements located around the refrigeration circuit the basis for diagnostics makes the DSU flexible and thus applicable to any suitable piece of equipment to be monitored.

Claims

1. A diagnostic sensor unit for monitoring and identifying faults in equipment such as refrigeration units (13 to 16), comprising a microprocessor module (21) including a microprocessor (22), a ROM (23), a RAM (24), an EEPROM (25), a system clock (26) and analogue to digital converter (ADC) (27) and a digital interface (28), powered by an independent power supply to the equipment being monitored, a plurality of inputs for connection to locations in the refrigeration equipment and a status indicator display, characterised in that the input from the locations is learnt by the microprocessor (22) and any change in the inputs from these locations is compared with the learnt inputs and significant changes indicated as faults on the display.

2. A diagnostic sensor unit as claimed in Claim 1, characterised in that the ADC (27) of the microprocessor module (21) is connected with temperature channels (29)and current channels (30), the digital interface (28) being connected to an opto-isolator circuit (31).

3. A diagnostic sensor unit as claimed in Claim 2, characterised in that the microprocessor module (21) is interfaced with a network communications package (32) and a serial communications package (33).

4. A diagnostic sensor as claimed in any preceding claim, characterised in that the plurality of inputs are two or more of temperature sensors (34), current sensors (30) and digital states.

5. A diagnostic sensor unit as claimed in any preceding Claim, characterised in that the diagnostic sensor unit (10) is connected to a data collection device (20).

6. A diagnostic sensor unit as claimed in Claim 5, characterised in that the data collection device (20) is a modem.

7. A diagnostic sensor unit as claimed in any preceding Claim, characterised in that the status indicator display is a liquid crystal display.

8. A refrigeration circuit comprising at least one refrigeration unit (13 to 16), a plurality of locations, designating physical parameters around the circuit, being connected to a control box (7) and a diagnostic sensor unit (10)as claimed in any of claims 1 to 8 in situ in the refrigeration circuit so that the diagnostic sensor unit (10) monitors and identifies faults in the refrigeration circuit.

9. A network system comprising a plurality of refrigeration units as claimed in Claim 8, characterised in that the refrigeration units (13 to 16) are connected in series by a network cable to a network power supply which is connected to a network controller (7).

10. A network system as claimed in Claim 9, characterised in that individual diagnostic sensor units (10) are linked on a network cable (17) which supplies electric power and communication media to the diagnostic sensor units (10).

11. A network system as claimed in Claim 10, charac-

terised in that the network power supply (18) is generated in a single mains transformer.

12. A network system as claimed in Claim 11, characterised in that the single mains transformer supplies up to thirty-two stations.

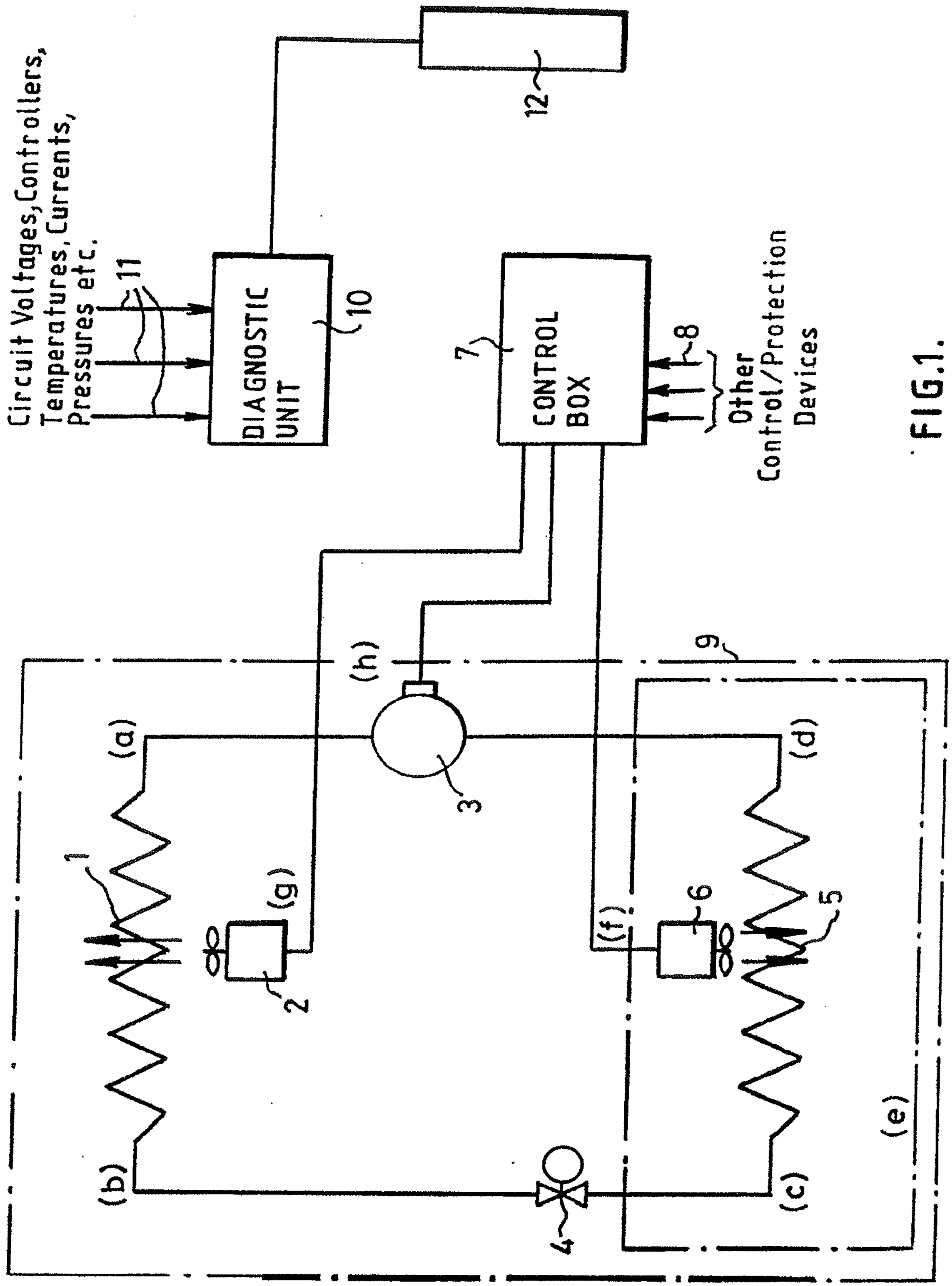
Circuit Voltages, Controllers,
Temperatures, Currents,
Pressures etc.
11
DIAGNOSTIC
UNIT
10
12
7
CONTROL
BOX
8
Other
Control/Protection
Devices
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
1
2
3
4
5
6
9

FIG.1.

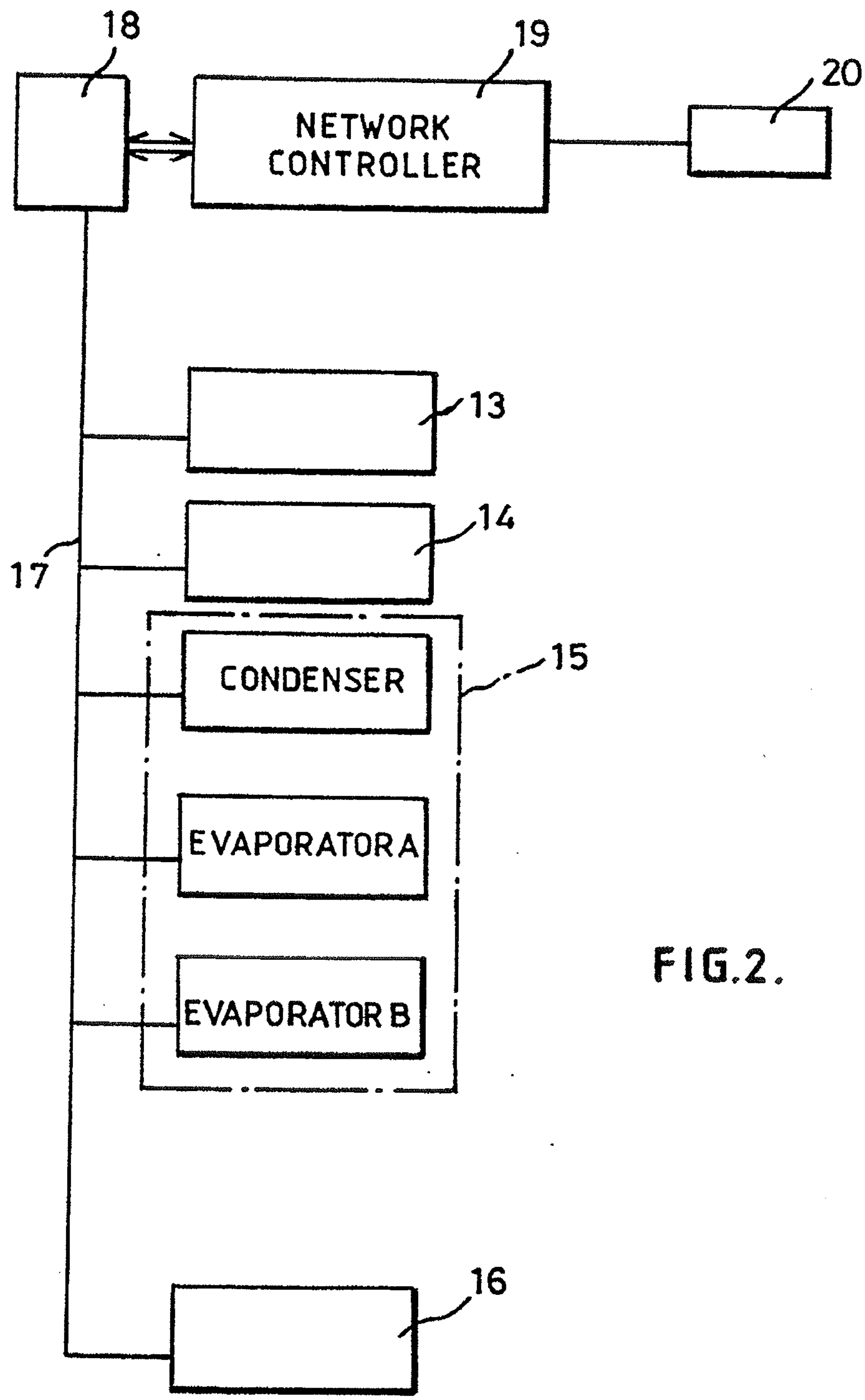
18
19
NETWORK
CONTROLLER
20
13
14
17
CONDENSER
15
EVAPORATOR A
EVAPORATOR B
16

FIG.2.

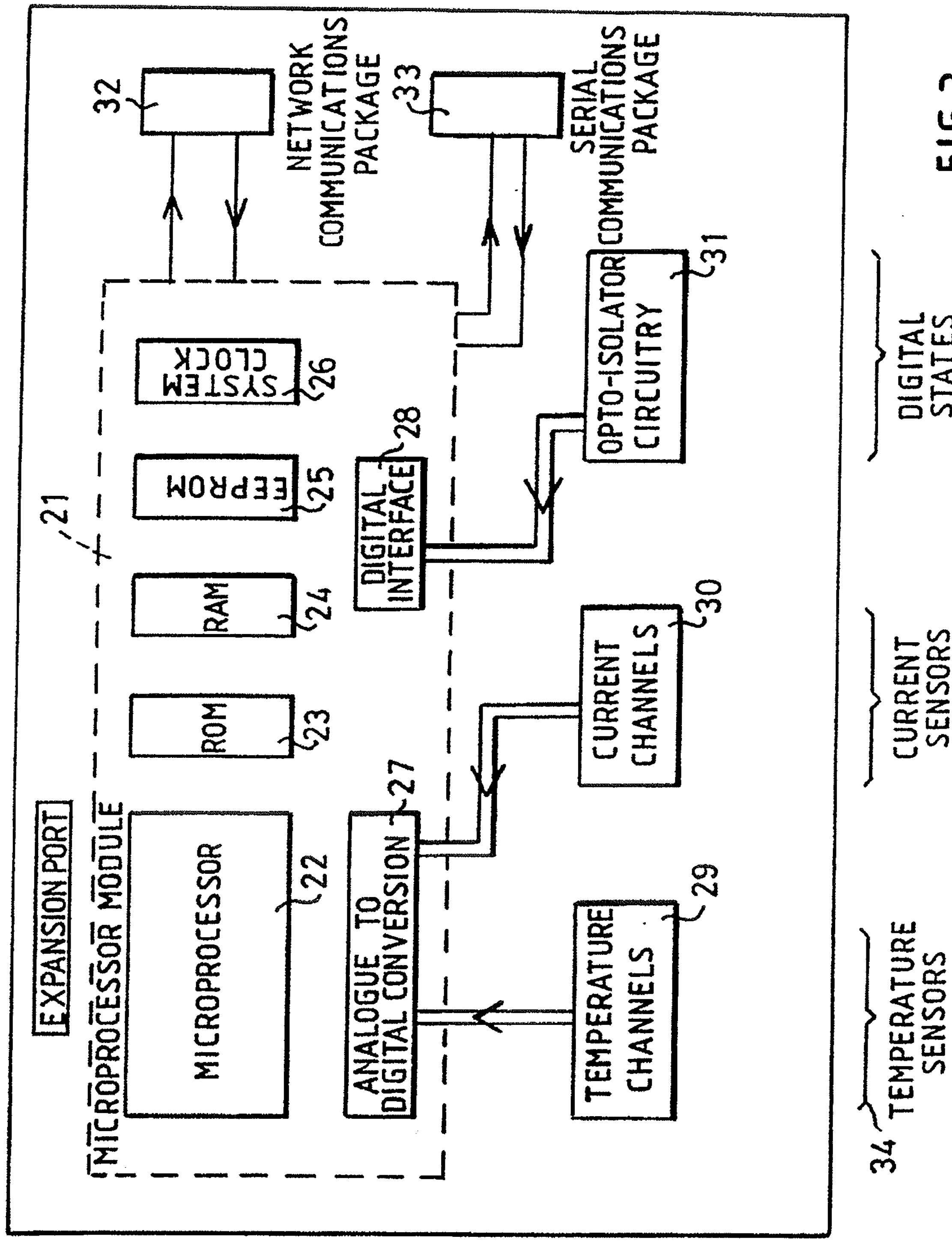
EXPANSION PORT
MICROPROCESSOR MODULE
21
MICROPROCESSOR
22
ROM
23
RAM
24
EEPROM
25
SYSTEM CLOCK
26
ANALOGUE TO DIGITAL CONVERSION
27
DIGITAL INTERFACE
28
TEMPERATURE CHANNELS
29
CURRENT CHANNELS
30
OPTO-ISOLATOR CIRCUITRY
31
32
NETWORK COMMUNICATIONS PACKAGE
33
SERIAL COMMUNICATIONS PACKAGE
34
TEMPERATURE SENSORS
CURRENT SENSORS
DIGITAL STATES

FIG.3.

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 91 30 3518

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X Y	FR-A-2 589 561 (FROILABO) * The whole document * ---	1,2,4,5 3,6-12	F 25 B 49/00 G 08 B 23/00
X	EP-A-0 254 253 (NIPPONDENSO CO., LTD) * Column 3, line 4 - column 5, line 38; figure 1 * ---	1,4,5	
X A	GB-A-2 064 818 (DAVY-LOEWY LTD) * Page 1, lines 29-67 * * Page 1, line 126 - page 2, line 15 * ---	1 2,4,5	
Y	FR-A-2 582 430 (EURAM-UMPI LIMITED ET UMPI ELETTRONICA SRL.) * The whole document * ---	3,6-7,8-11	
A Y	WO-A-8 703 988 (MONITRONIX LTD) * Page 3, line 5 - page 4, line 29; figures 1-4 * * Page 6, line 33 - page 7, line 20; figure 7 * ---	3,5-10 12	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	WO-A-8 802 527 (SHEPHERD INTELLIGENCE SYSTEMS) * Page 4, line 12 - page 7, line 26; figures 1-3,5 * ---	3,6,8-11	F 25 B G 08 B
A	US-A-4 653 280 (HANSEN et al.) * The whole document * ---	1,2,5,7,8	
A	US-A-4 660 386 (HANSEN et al.) * The whole document * --- -/-	1,2,5,7,8	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-07-1991	REEKMANS M.V.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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& : member of the same patent family, corresponding document

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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
A	EP-A-0 351 833 (MITSUBISHI JUKOGYO K.K.) * Page 4, lines 1-14; page 4, line 49 - page 5, line 15 * ---	1	
A	FR-A-2 628 558 (SCL., SECURITY COMPUTER LINE S.R.L.) * Claims * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)

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THE HAGUE	22-07-1991	REEKMANS M.V.

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